

## Observations of the early postembryonic development and dispersal of the purse-web spider *Calommata signata* (Araneae: Atypidae)

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**Abstract** — The early postembryonic development of *Calommata signata* (Araneae: Atypidae) was observed under laboratory conditions. Observations of the inside of the burrow of a pregnant female indicated that postembryonic spiderlings molted into the first instar between the silk layers of the inner wall. Subsequently, they moved to the inner space of the mother's burrow, whereupon they molted to the second instar stage. Finally, it was clear that the second instar dispersed from the mother's burrow similar to other atypid spiders. In addition, we also observed the dispersal behavior of *C. signata* in the laboratory as well as in the field to confirm their dispersal method. From the field observation, we confirmed that the dispersal of *C. signata* occurred in the summer, and that their dispersal method is similar to those of other atypids.

**Key words** — purse-web spider, Atypidae, *Calommata*, postembryonic development, ballooning

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### Introduction

Although most non-araneomorph spiders do not use ballooning as a dispersal method, the aerial dispersal of spiderlings, or pre-ballooning behavior, has been previously reported in three mygalomorph families, Atypidae (*Atypus* and *Sphodros* spp.), Ctenizidae (*Conothele* and *Ummidia* spp.) and Actinopodidae (*Missulena* and *Actinopus* spp.) (Coyle 1983, 1985; Bell et al 2005; Eberhard 2005; Ferretti et al. 2013; Fisher et al. 2014). Unlike araneomorphs, which use ballooning as a dispersal strategy, these mygalomorph spiderlings were observed to move along bands of silk lines and then launch themselves into the air after dangling at the ends of draglines. Although this dispersal method is thought to be more primitive and likely less effective than the ballooning of araneomorph spiders, it can significantly increase the vagility of spiderlings using this method (Coyle 1983). Additionally, it has been considered that examinations of the dispersal behavior and abilities in mygalomorph spiderlings lead to an understanding of the evolution of spider web (Eberhard 2005; Ferretti et al. 2013).

Examinations of postembryonic development may help understand spiderling dispersal in mygalomorph spiders, as the body size of spiderlings is an important factor in

effective dispersal by ballooning (Valerio 1975). However, descriptions of embryonic development in spiders are less straightforward, as the developmental stage at which hatching occurs may vary between species (Foelix 2011). For example, Yoshikura (1972) indicated that the post-hatched spiderlings of the genus *Conothele* are referred to as prelarva by Vashon (1957, quoted in Yoshikura 1987), whereas the spiderlings of the genus *Atypus* are at a more advanced developmental stage (i.e., larva). In addition, the number of molting events in the egg sac also varies between species (Yoshikura 1987).

In Japan, previous studies have reported spiderling dispersal of two atypid spiders, *Atypus karschi* Dönitz 1887 and *Calommata signata* Karsch 1879, and have suggested that these spiderlings also display dispersal methods similar to those of the aforementioned mygalomorph spiders: the spiderlings dropped down on their draglines and were blown off (Katsura 1975; Hamamura 1981; Sato et al. 2007; Okumura 2015). These studies inferred that the aerial dispersal of spiderlings is common in atypid spiders. However, there was no attempt to compare the dispersal instar among atypid spiders, as the postembryonic development of *Calommata* species has not yet been described. Therefore, in this study, we observed the postembryonic development of the atypid spider *C. signata* from egg to

spiderling dispersal to compare with that of other atypid spiders. In addition, this study also included both field and laboratory observations of the dispersal behavior of *C. signata* spiderlings to confirm their dispersal method.

### Materials and methods

In this study, both the collection of *C. signata* females and field observations of spiderling dispersal were performed at the Funabashi Campus, College of Science and Technology, Nihon University, Funabashi, Chiba, Japan.

To observe the early postembryonic development of *C. signata*, we prepared a plastic container of diameter 7.5 cm and height 13.5 cm with a removable side. A pregnant female of *C. signata* collected on 23 November 2008 was allowed to reconstruct a burrow in soil maintained in the container at room temperature. The side of the container was opened irregularly to observe postembryonic development inside the burrow. During the observation, some spiderlings that were hatched and growing in the mother's burrow were collected for observation.

Two pregnant females were collected on 31 October and 20 November 2005 to observe spiderling dispersal in laboratory. These spiders also reconstructed their burrows in soil maintained in plastic containers and were kept at room temperature. Field observations of the dispersal events were performed from 6 to 8 August 2008. The dispersal behaviors in the field were video-documented using a digital camera. The movie data of this study is available at the Movie Archives of Animal Behavior (<http://www.momo-p.com/>). In addition, we tracked silk trails constructed by the dispersing spiderlings in the summers of 2009 and 2010 to confirm the period of the dispersal in the field.

### Results

#### Postembryonic development from egg to dispersal in *C. signata*

The early postembryonic development of *C. signata*, from egg to spiderling dispersal, was observed under laboratory conditions. In the present study, although various terms have been used for the description of spider instar (Foelix 2011), according to Downes (1987) and other recent studies (e.g. Wolf & Hibrant 2011; Hibrant & Damen 2015), the stage just after hatching is called "postembrio instar". Likewise, "first instar" begins after the first molting, and the next molting results in "second instar".

About one month after the reconstruction of the burrow in the container, the spider closed the burrow entrance tightly. On 16 January 2009, approximately two weeks after closing the burrow entrance, an egg mass was found near the bottom of the burrow (Fig. 1). The egg mass appeared to be buried between the layers of the inner wall, and thus we could not distinguish the egg sac from the silk layered wall of the burrow. The eggs were whitish yellow and were on average 1.18 mm in diameter ( $SD=0.04$ ,  $n=20$ ). The granular structures on the chorion bonded the eggs tightly together, as well as with the silk layer of inner wall.

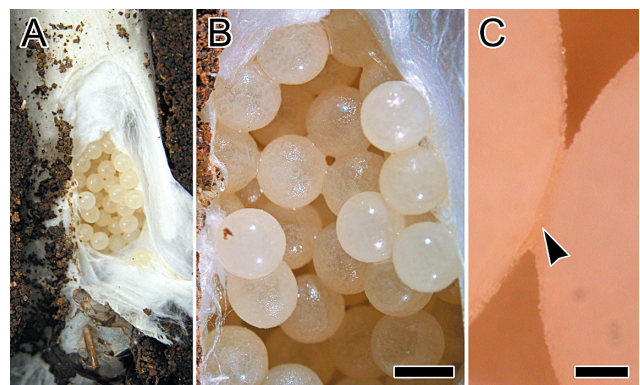
Twenty-one days after discovering the eggs, hatched spiderlings were observed between the silk layers of the inner wall (Fig. 2). The postembrio instar spiderlings of *C. signata* were creeping, were on average 1.85 mm long ( $SD=0.19$ ,  $n=6$ ) with an average carapace width of 0.62 mm ( $SD=0.03$ ,  $n=6$ ), and were milky white in color. The rounded spiderlings looked quite different from the adult morphology. They did not have seta or differentiated claws, and chelicerae and spinnerets were identified but incomplete.

The first apparent molting event was undertaken between the silk layers 14 days after hatching (Fig. 3). The first instar spiderlings were active, were on average 2.40 mm long ( $SD=0.10$ ,  $n=12$ ) with an average carapace width of 0.62 mm ( $SD=0.02$ ,  $n=12$ ), and were milky white in color. In this stage, the appearance of the spiderlings was generally similar to the adult form. Chelicerae with long fangs, seta, and claws were able to be observed, and the segmentation of spinnerets was present. After eight days, we confirmed that these spiderlings emerged from the layered inner wall and moved to the inner space in which the mother spider resides.

The second molting event was confirmed to take place in the inner space of the burrow 25 days after first molting (Fig. 4). Second instar spiderlings were on average 2.68 mm long ( $SD=0.16$ ,  $n=14$ ) with an average carapace width of 0.67 mm ( $SD=0.02$ ,  $n=14$ ). Their form and color resembled those of the adult, although they were small and sexually immature. These spiderlings spent 14 days in the mother's burrow and then dispersed from the burrow on 31 March 2009. New exuviae were not found in the inside of the burrow after the second molting and dispersal, clearly indicating the dispersal of *C. signata* following second molting. These spiderlings could construct the silk lined burrow and capture prey as well as adults.

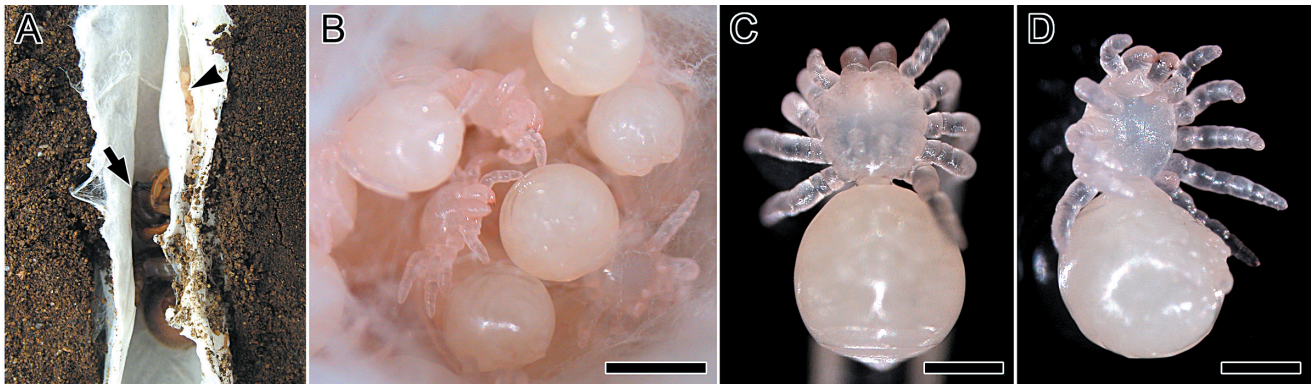
#### Dispersal of *C. signata*

For laboratory observations of dispersal, two pregnant females collected in the autumn of 2005 were used to confirm

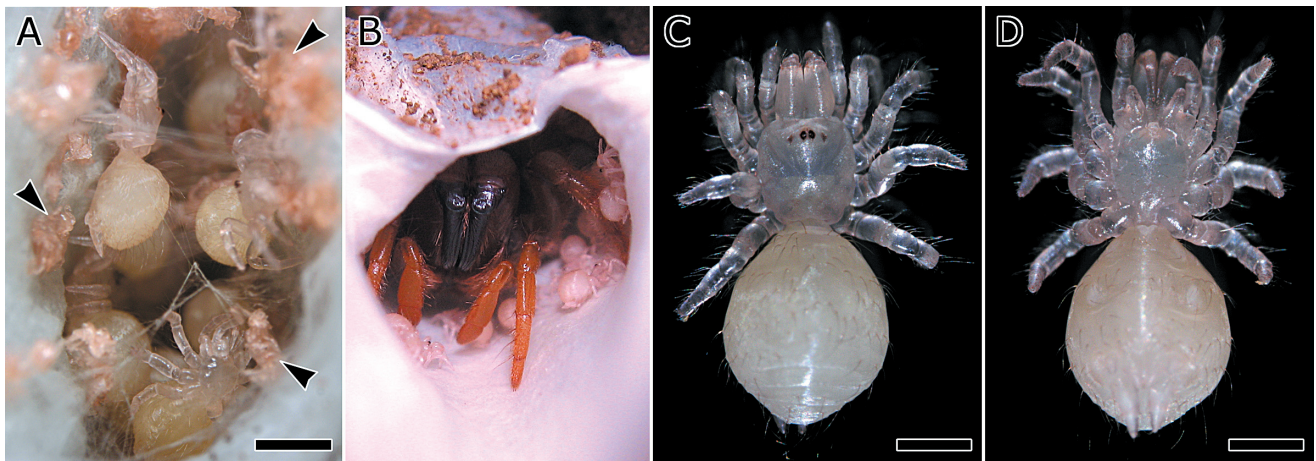


**Fig. 1.** Egg mass within the burrow of *Calommata signata*. A, egg mass at the bottom end of the burrow; B, enlarged image of the egg mass; C, enlarged image of the chorion, the arrow head indicates the bond between eggs. Scales = 1 mm (B); 0.1 mm (C).

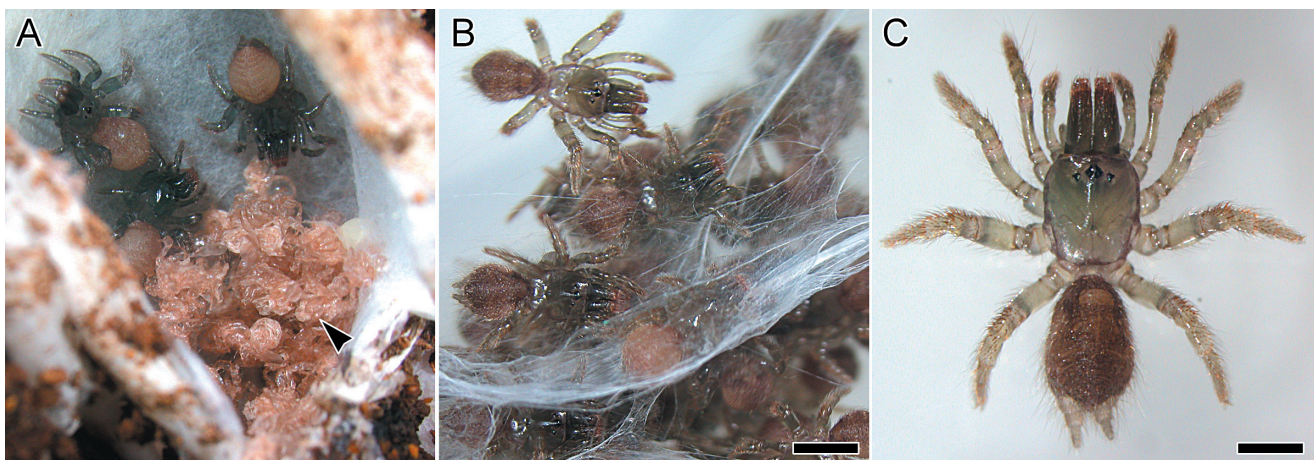




**Fig. 2.** Postembryo instar spiderlings of *Calommata signata*. A, opened burrow, an arrow and arrow head indicates the mother spider and spiderlings between the silk layers of the inner wall, respectively; B, enlarged image of spiderlings between silk layers; C, dorsal view of a spiderling; D, ventral view of a spiderling. Scales = 1 mm (B); 0.5 mm (C–D).

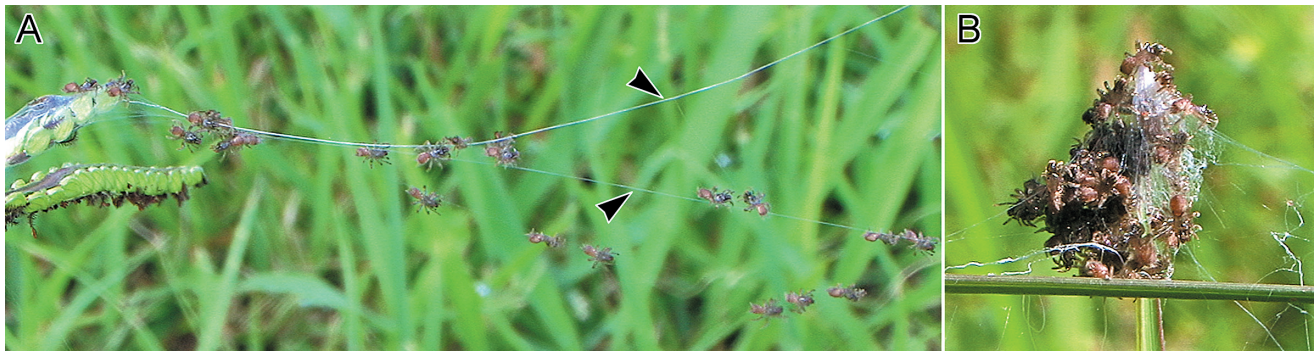


**Fig. 3.** First instar spiderlings of *Calommata signata*. A, spiderlings molting between the silk layers of the inner wall, arrow heads indicate exuviae; B, mother spider with spiderlings emerging from the inner wall into the inner space; C, dorsal view of a spiderling; D, ventral view of a spiderling. Scales = 1 mm (A); 0.5 mm (C–D).

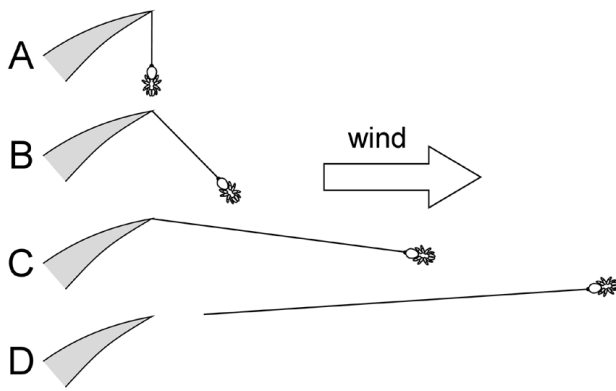


**Fig. 4.** Second instar spiderlings of *Calommata signata*. A, spiderlings molting in the inner space of the burrow, an arrow head indicates exuviae; B, spiderlings after dispersal from the mother's burrow; C, dorsal view of a spiderling. Scales = 1 mm (B); 0.5 mm (C).





**Fig. 5.** Dispersal of *Calommata signata*. A, silk trails conducted by spiderlings, arrow heads indicate silk aerial bridges between the tips of plants; B, ball of spiderlings formed at the tip of a plant. The associated movie is available at the Movie Archives of Animal Behavior (<http://www.momo-p.com/>; Kuwada-Kusunose 2016).



**Fig. 6.** Diagrammatic representation of the aerial dispersal. A, spiderling drops down on the dragline; B–C, wind pushes spiderling away from the attachment point as dragline lengthens; D, dragline breaks and the spiderling is blown off.

the number of broods per female. The dispersal of their broods was observed in April 2006. The total numbers of brood from each of the two burrows were 134 and 220, respectively. Each brood emerged from the mother's burrow within two days. Although the spiderlings dispersed in spring under laboratory conditions, dispersal in the field was observed from 5 to 7 August 2008. In addition, we found silk trails constructed by spiderlings on 17 and 23 July 2009 and 17, 23–25, and 30–31, July 2010.

Dispersal in the field occurred not only during morning hours (7:00–9:00am) but also on a cloudy afternoon (13:00–14:00). Silk trails extended irregularly by branching and converging, forming silk mats and aerial bridges between the tips of plants in some places. The spiderlings walked several meters along the silk trails laid by previous spiderlings, occasionally forming a ball of spiderlings (Fig. 5; Kuwada-Kusunose 2016). When the spiderlings reached the tips of plants, they dropped down on their draglines. The spiderlings were blown and were away from the attachment point by lengthening the dragline. Most of the spiderlings landed in the immediate area. However, it was infrequently observed that the spiderlings were blown off

and drifted through the air via the wind when the lengthening dragline broke (Fig. 6).

### Discussion

Our laboratory observations indicated that *C. signata* developed though the second instar in the mother's burrow, after which they dispersed prior to subsequent molting events. It has been suggested that the early postembryonic development of *C. signata* is very similar to that of *A. karschi* which consists of two phases (i.e., larva and prenymph according to Vachon's classification) prior to dispersal at nymph stage (Yoshikura 1958). To our knowledge, this is the first observation of the early postembryonic development of any *Calommata* species. The characteristics of postembryo instar of *C. signata* were almost identical with those of embryos of *A. karschi* just after hatching, which is referred to as the deutovum stage by Yoshikura (1958). The deutovum stage corresponds to the larva stage defined by Vachon (1957, quoted in Yoshikura 1987). And the morphological characteristics of first instar of *C. signata* show similarity with those of the first postembryonic stage (i.e., Vachon's prenymph stage) of *A. karschi* (Yoshikura 1958). In addition, as in previous studies (Hamamura 1981; Sato et al. 2007; Okumura 2015), we confirmed that the dispersal of *C. signata* occurred over several days during the summer, and that the dispersal method of *C. signata* is very similar to the ballooning method previously observed in other atypids (e.g. Katsura 1975; Coyle 1983, 1985). However, it is widely accepted that spiderlings of *A. karschi* and *Sphodros abboti* disperse in spring and autumn, respectively (Coyle & Shear 1981; Yoshikura 1987), suggesting that the season when dispersal occurs varies among atypid species.

Coyle & Shear (1981) described the process from hatching to dispersal of *S. abboti* as follows: First instar spiderlings molt into second instars inside the egg sac in the mother's burrow. After emerging from egg sac, the spiderlings molt into third instars in the mother's burrow. These third instar spiderlings are equipped at this stage with the abilities to both construct a burrow and handle prey as

well as adults. By comparison, the first instar, second instar and third instar stages described by Coyle & Shear (1981) correspond to the postembryonic instar, first instar, and second instar as defined by Downes (1987), respectively. It is also important to note that, despite differences in developmental terminology, the process from hatching to dispersal in *C. signata* is identical to that of *S. abboti*. On the other hand, although spiderlings of *A. karschi* also dispersed from the mother's burrow after the second true molting to begin their independent life, both the first and second molting events were observed to take place within the egg sac (Yoshikura 1958; Miyashita 1992). These results suggest that dispersal after the second molting is common, but that the location where the second molt occurs is not the same for all atypid spiders.

In conclusion, it has been suggested that although atypid spiders adopted the same dispersal method at the second instar stage, there are variations in both the dispersal season and the timing of emergence from the egg sac. Although causes and benefits of the variation in dispersal of atypids remain unclear, the observation of variations in behavioral and developmental processes associated with dispersal may provide a useful cue for the elucidation of the diversity of dispersal strategies in mygalomorphs.

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#### References

- Bell, J. R., Bohan, D. A., Shaw, E. M. & Weyman, G. S. 2005. Ballooning dispersal using silk: world fauna, phylogenies, genetics and models. *Bull. Entomol. Res.*, 95: 69–114.
- Coyle, F. A. 1983. Aerial dispersal by mygalomorph spiderlings (Araneae, Mygalomorphae). *J. Arachnol.*, 11: 283–286.
- Coyle, F. A. 1985. Ballooning behavior of *Ummidia* spiderlings (Araneae, Ctenizidae). *J. Arachnol.*, 13: 137–138.
- Coyle, F. A. & Shear, W. A. 1981. Observations on the natural history of *Sphodros abboti* and *Sphodros rufipes* (Araneae, Atypidae), with evidence for a contact sex pheromone. *J. Arachnol.*, 9: 317–326.
- Downes, M. F. 1987. A proposal for standardization of the terms used to describe the early development of spiders, based on a study of *Theridion rufipes* Lucas (Araneae: Theridiidae). *Bull. Br. Arachnol. Soc.*, 7: 187–193.
- Eberhard, W. G. 2005. Dispersal by *Ummidia* spiderlings (Araneae, Ctenizidae): ancient roots of aerial webs and orientation? *J. Arachnol.*, 34: 254–257.
- Ferretti, N., Pompozzi, G., Copperi, S. & Schwerdt, L. 2013. Aerial dispersal by *Actinopus* spiderlings (Araneae: Actinopodidae). *J. Arachnol.*, 41: 407–408.
- Fisher, J. R., Fisher, D. M., Skvarla, M. J. & Dowling, A. P. G. 2014. Pre-ballooning in *Ummidia* Thorell 1875 (Araneae: Ctenizidae) from the Interior Highlands, USA: second account from the region and review of mygalomorph ballooning. *J. Arachnol.*, 42: 318–321.
- Foelix, R. F. 2011. *Biology of Spiders*. 3rd edition. Oxford Univ. Press, Oxford, 419 pp.
- Hamamura, T. 1981. [The brood cluster of *Calommata signata* (Araneae: Atypidae)]. *Atypus*, 79: 26–27. (In Japanese)
- Hilbrant, M. & Damen, W. G. 2015. The embryonic origin of the ampullate silk glands of the spider *Cupiennius salei*. *Arthropod Struct. Dev.*, 44: 280–288.
- Katsura, K. 1975. A note on ballooning of *Atypus karschi*. *Atypus*, 64: 6. (In Japanese)
- Kuwada-Kusunose, T. 2016. Dispersal of *Calommata signata*. Movie Archives of Animal Behavior Data No.:momo160401cs01b (<http://www.momo-p.com/showdetail-e.php?movieid=momo160401cs01b>).
- Miyashita, K. 1992. Postembryonic development and life cycle of *Atypus karschi* Dönitz (Araneae: Atypidae). *Acta Arachnol.*, 41: 177–186.
- Okumura, K. 2015. [Observation of the spiderling dispersal of *Calommata signata* (Araneae: Atypidae)]. *Kishidaia*, 106: 1–3. (In Japanese)
- Sato, T., Wada, T., Nakashima, C. & Tsurusaki, N. 2007. New records of *Calommata signata* (Araneae: Atypidae) from eastern part of Tottori Prefecture, Honshu, Japan. *Nat. Hist. Res. San'in*, 3: 6–10. (In Japanese)
- Valerio C. E. 1975. Population Structure in the Spider *Achaearanea tepidariorum* (Araneae, Theridiidae). *J. Arachnol.*, 3: 185–190.
- Wolff, C. & Hilbrant, M. 2011. The embryonic development of the central American wandering spider *Cupiennius salei*. *Front. Zool.*, 8: 15; doi: 10.1186/1742-9994-8-15
- Yoshikura, M. 1958. On the development of a purse-web spider, *Atypus karschi* Dönitz. *Kumamoto J. Sci. B*, 3: 73–86.
- Yoshikura, M. 1972. Notes on the development of a trap-door spider, *Ummidia fragaria* (Dönitz), *Acta Arachnol.*, 24: 29–39.
- Yoshikura, M. 1987. *The Biology of Spiders*. Japan Scientific Societies Press, Tokyo, 613 pp. (In Japanese)

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